AEC-NASA TECH BRIEF

Possible Correlation Between Work-Hardening and Fatigue-Failure
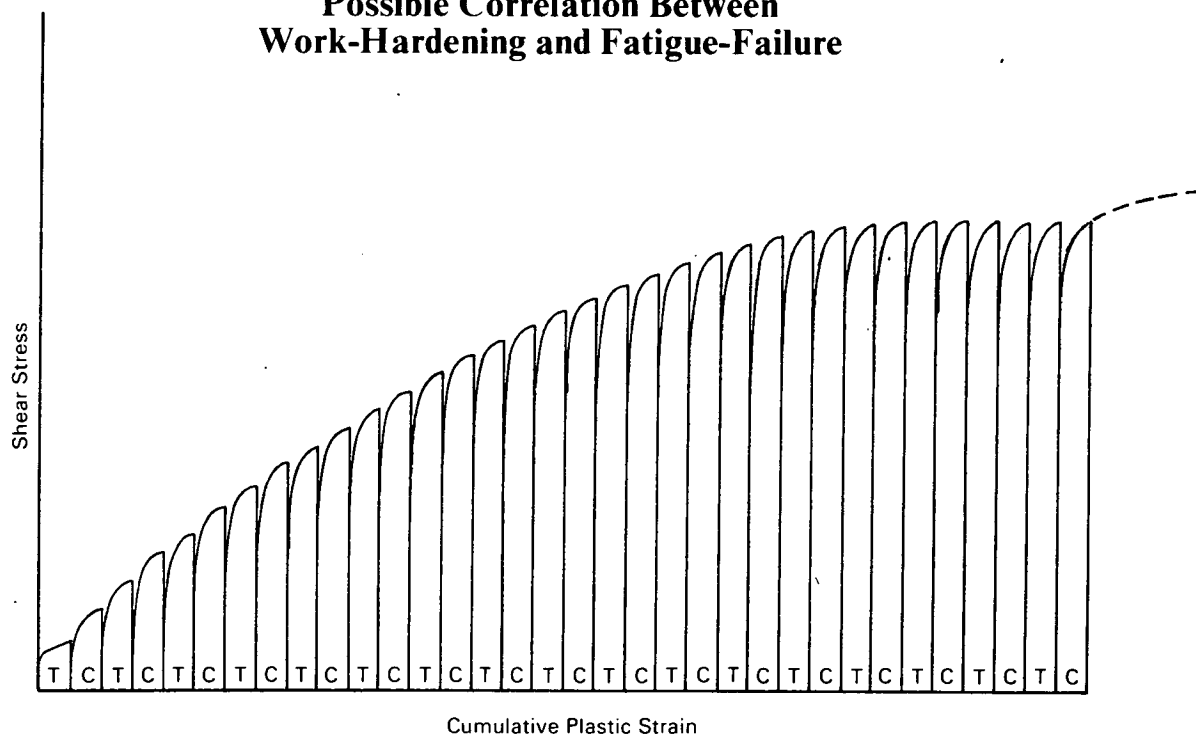

Fig. 1. "Fatigue hardening" (schematic): at constant prescribed plastic-strain amplitude, the observed shear-stress amplitude increases with increasing number of cycles (solid line). The flow stress, as measured in an interposed tensile test, may rise even more (dashed line), T, Tension; C, Compression.

A conceptual theory for the correlation of strain-hardening with fatigue-failure has been presented (1). It is proposed that cyclic hardening due to non-uniform strain and stress amplitudes during testing, especially during the initial application of stress to a specimen, may correlate positively with the ultimate strength of the specimen under test. The work is a logical treatment of the problems involved in fatigue-failure analyses.

Fatigue tests can be done at constant stress amplitude or at constant strain (or plastic-strain) amplitude. Schematic diagrams of stress versus cumulative plastic strain for these two cases are shown (Figs. 1 and 2). The stress, needed for maintenance of a constant plastic-strain amplitude, increases as the number of cycles increases ("fatigue hardening") until, after some hundreds or thousands of cycles, it reaches a saturation value (Fig. 1).

Conversely, in a test done at constant stress amplitude, the plastic strain per half-cycle decreases as the number of cycles increases until, after some hundreds or thousands of cycles, it reaches an approximately constant value (Fig. 2).

During the stage of saturation, both strain and stress amplitudes are thus constant, no matter which is prescribed. During the initial hardening period, however, there are substantial differences in the behavior of the material for the two different boundary conditions. These differences may have a profound effect upon whether or not fatigue-failure eventuates (1).

It is shown that, while the structural changes leading to eventual fatigue-failure occur throughout the entire test, the very possibility of structural changes, during the long stage of saturation, depends on the mean free-slip area of individual dislocation segments during this stage; this in turn depends on the degree of cyclic hardening during the first few hundred cycles. This hardening depends sensitively on the exact boundary conditions.

If the cyclic hardening is related to the work-hardening coefficient in a monotonic test to the same stress level, the endurance level correlates with the beginning of low work-hardening. This fact may explain the phenomenological correlation between endurance limit and ultimate tensile strength. The latter, like the former, is determined by a critically low work-hardening rate and not by a crack-nucleation or crack-propagation stress.

Reference:

1. P. O. Kettunen and U. F. Kocks, "On a possible relation between work hardening and fatigue failure" (Argonne National Laboratory, May 1967).

Notes:

1. This problem is currently of significant interest; any work toward its solution will interest the steel and aluminum industries, as well as manufacturers of almost all nonstatic systems—the aircraft, marine, construction, power, and machine-tools industries.

2. Inquiries may be directed to:
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Patent status:

Inquiries concerning rights for commercial use of this innovation may be made to:
   Mr. George H. Lee, Chief
   Chicago Patent Group
   U.S. Atomic Energy Commission
   Chicago Operations Office
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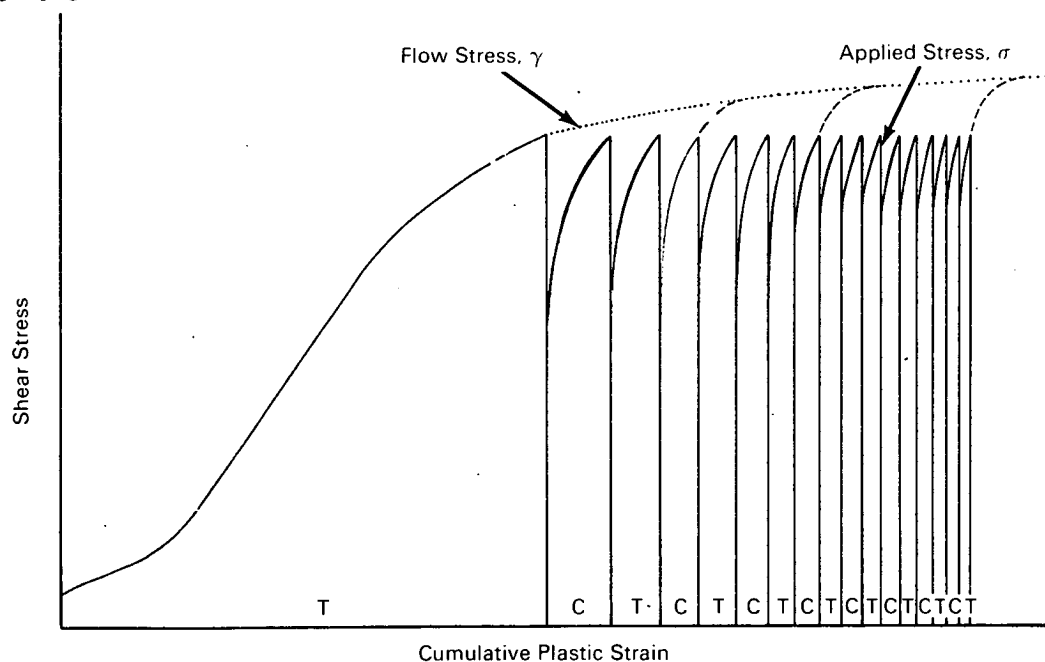   Argonne, Illinois 60439

Fig. 2. "Cyclic hardening" (schematic): at constant prescribed shear-stress amplitude, the observed plastic-strain amplitude decreases with increasing number of cycles (solid line); the flow stress as measured in an interposed tensile test rises above the applied stress amplitude (dashed lines). T, Tension; C, Compression.